International Journal of Science and Mathematics Education (2020) 18:1023–1040
https://doi.org/10.1007/s10763-019-10005-4

Students' Construct and Critique of Claims and Evidence Through Online Asynchronous Discussion Combined with In-Class Discussion

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Received: 2 January 2019 / Accepted: 18 July 2019 / Published online: 8 August 2019

Abstract
This study examines how grade 5 students engage with the aspects (construct and critique) of argument in an online asynchronous discussion combined with in-class wrap-up discussion. Grade 5 students in a rural public school engaged in a "human health investigation" unit using an argument-based inquiry approach followed by online asynchronous discussions using a Moodle forum. The online discussion was wrapped up by a 1-h in-class discussion and student writing of claims, evidence, and reflection. Data sources included online notes posted by 111 students in the Moodle forum, a video record of in-class discussion, and writing samples of claims, evidence, and reflections produced by 54 students after online and in-class discussions. Results of this study indicate that students engaged with the construct and critique components of argument in the online asynchronous discussion and in the in-class wrap-up discussion. The results show that in terms of the argument components they (a) used evidence resources to challenge and supplement arguments, (b) critiqued and reinforced evidence, and (c) strongly negotiated and confirmed/revised claims.

Keywords Argument-based inquiry · Online asynchronous discussion · Student argument · Student reflection

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10763-019-10005-4) contains supplementary material, which is available to authorized users.

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Introduction

Recent curricula changes that have taken place in many countries have focused much attention on argumentation as a reflection of how science knowledge is constructed. The Next Generation Science Standards, for example, emphasizes the importance of student engagement in constructing and negotiating valid arguments while they do scientific practice (National Research Council (NRC), 2013). In this respect, the Science Writing Heuristic (SWH) approach, an argument-based inquiry approach was used to promote students' argumentation during their scientific inquiry investigations in this study (Keys, Hand, Prain, & Collins, 1999). Importantly, the development of arguments can be viewed as being framed not only within an in-class communication frame but also through online discussions that promote opportunities for students to be engaged in dialogic argumentation (Clark & Sampson, 2008; Joiner & Jones, 2003; Schellens & Valcke, 2006). Tsai (2015) reported that using online argumentation could improve the students' scores for the PISA scientific competencies, especially for "using scientific evidence" and "identifying scientific issues." In particular, online asynchronous discussions allow students time to propose, read, evaluate, reflect, critique, and prepare responses which are typed in written texts (Clark, D'Angelo, & Menekse, 2009; Clark, Sampson, Weinberger, & Erkens, 2007; Tiene, 2000). Andresen (2009) in a review of asynchronous discussion forums claimed that "asynchronous discussion forum may form part of a more generalized model of learning - a blended learning approach (p. 254)." His claim implied that online asynchronous argumentation should be a valuable addition to, rather than a substitute for, in-class discussion (Tiene, 2000; Tsai, 2015). In this study, grade 5 students conducted a scientific inquiry investigation using an argument-based inquiry approach that stimulated them to negotiate their ideas throughout the inquiry investigations in class. Then, the students were engaged in online asynchronous discussion combined with in-class wrap-up discussion about their completed inquiry investigation. The online discussion opportunities followed by in-class wrap-up discussion was added to argument-based inquiry as a means to extend students' in-class argumentation in our study setting. We were interested in examining how grade 5 students engage with the aspects (construct and critique) of argument in the online asynchronous discussion combined with in-class wrap-up discussion (ODID) along with argument-based inquiry.

Theoretical Framework

This study was guided by social constructivism as a theoretical framework (Powell, 2009), in that we examined students' claims and evidence developed through online and follow-up in-class discussions along with argument-based inquiry. Social constructivism views collaboration and social interaction as the chief method for learning (Powell, 2009). As students socially interacted through online discussion combined with in-class discussion along with argument-based inquiry, their claims and evidence as forms of knowledge could be socially communicated, negotiated, critiqued, validated, and reconstructed. In this study, students were engaged in an argument-based inquiry before engaging in online discussion. The argument-based inquiry approach provides both teacher and student templates and promotes students' verbal and written discussions about questions, procedure, claims, and evidence in inquiry investigations (Keys et al., 1999).

"Social constructivism" refers here to Vygotshy (1962) for the argument-based inquiry approach and refers to Doise, Mugny, and Perret-Clermont (1975) for online discussion and in-class wrap-up discussion. While the "zone of proximal development" by Vygotshy (1962) emphasized adult guidance or in collaboration with more capable peers in problem-solving, Doise et al. (1975) argued that the development of operational thought is facilitated when several individuals are required to coordinate their actions. The teacher guided students to propose claims and evidence during the argument-based inquiry investigation rather than simply use a transmission of knowledge approach. That is, the teacher promoted the development of the appropriate use of argument language—question, claims, and evidence—through socially negotiated class discussions. The role of the teacher in this study was to provide information in regard to an inquiry investigation and to guide and facilitate student engagement in argument-based inquiry with importance placed on the teacher not interrupting students' online discussion and in-class wrap-up discussion. Argument-based inquiry in this study is based on social interaction between students and the teacher as well as between students during argument-based inquiry investigation. Online argumentation and in-class wrap-up discussion is based on social interaction between students in this study.

Argumentation to Learn Science

Argumentation in both oral and written forms has been highlighted as a central feature of scientific practices (Ford, 2008a, 2008b; NRC, 2013). The Science Writing Heuristic (SWH), an Argument-Based Inquiry (ABI) approach that incorporates verbal and written argument into scientific inquiry, could be used as a framework to help students construct scientific knowledge within scientific inquiry (Keys et al., 1999). Sampson, Grooms, and Walker (2011) have also proposed that Argument-Driven Inquiry (ADI) can be used as a template or guide to design laboratory activity that provides opportunity for students to participate in argumentation embedded in scientific inquiry practices. These two approaches both address the idea of argument in scientific inquiry. Importantly, ABI places much more emphasis on student generation of the question and reflection as a critical element of inquiry process (Choi, Hand, & Greenbowe, 2013). Teachers engage students to generate their own inquiry questions and bring reflection to their understanding of the laboratory concepts. ADI includes peer review that students are required to provide explicit feedback to the author about what needs to be done to improve the quality of the inquiry investigation report (Sampson et al., 2011).

The National Research Council (2013) stimulates that students should be given opportunities to engage in the practice of providing evidence to support claims, persuade their peers, and ask relevant questions. This reform document emphasizes that students understand scientific concepts as they engage in the practices of argumentation by which such ideas are developed and refined. As argued by Richmond and Striley (1996), the construction of scientifically appropriate arguments builds scientific knowledge. In a study trying to scaffold student arguments by using software which offered explanations and evidence, Bell and Linn (2000) noticed that students who offered more evidence made more links among their ideas and thereby made conceptual progress. Zohar and Nemet (2002) also suggested that argumentation instruction and practice can improve conceptual understanding. Golanics and Nussbaum (2008) argued that students' development of argument may depend on their engagement and ownership in the topic. These research studies indicate that students learn science while they are engaged in writing, analyzing, reasoning, sharing, and discussing findings about their scientific inquiry (Driver, Newton, & Osborne, 2000; Kelly & Chen, 1999).

Beyond face-to-face argumentation, online learning environment has been used to engage students in discussions and help them learn science (Clark & Sampson, 2008; Joiner & Jones, 2003; Schellens & Valcke, 2006). As online asynchronous discussions allow students time to read, reflect, and prepare responses that are typed in written texts, students would feel more comfortable and less aggressive and voice their opinions in more equal opportunities (Tiene, 2000; Wang & Woo, 2007). Hoadley and Linn (2000) found that students gain integrated understanding of science concepts from asynchronous online discussion. In a study statistically analyzing coded discussion transcripts to test several hypotheses on knowledge construction, Schellens and Valcke (2006) claimed that collaborative learning in asynchronous discussion improved task orientation and student knowledge construction. Lin, Hong, Wang, and Lee (2011) also reported that students' experiences of analyzing and reflecting on ideas and comments in asynchronous online discussion were beneficial for constructing their conceptual understanding. Taken together, research studies have emphasized online learning environments as having the potential to be influential for student conceptual understanding.

Analysis of Online Argumentation

Online learning environments have been emphasized as opportunities for students to engage in *online discussion*, in particular *dialogical argumentation* (Lin, Hong, & Lawrenz, 2012; Oliveira, Tinoca, & Pereira, 2011). While "argument" or "argumentation" include discussion of claims, and evidence, we would argue that "discussion" does not necessarily include argumentation or argument as participants would simply brainstorm ideas, share information, and ask simple questions, and so on. As students evaluate, critique, and refine scientific ideas in online learning environment, they should be engaged in argumentation in online learning environment. As defined by McNeill and Pimentel (2010), the term of argumentation has meaning in terms of both structural and dialogic aspects. The structural aspect refers to argument as the justification of knowledge claims using evidence. The dialogic aspect refers to argumentation as persuasion, negotiation, or the interaction that occurs between individuals about the validity of their knowledge claims. As argued by Ford (2008a, 2008b), construction and critique of claims are two critical aspects of "practices of scientists" (Ford & Forman, 2006). Online discussion settings provided students with opportunities of engaging in a series of different negotiation ranging from individual, small group, to whole class, which involve them in the practices of scientists (Ford, 2008a, 2008b). In this respect, studies analyzing online argumentation would provide important implications on student science learning.

As reviewed by Clark et al. (2007), previous studies have assessed dialogic argumentation in online learning using analytic frameworks focusing on formal argumentation structure, nature, and function of contributions within the dialog and argumentation sequences and interaction patterns. Joiner and Jones (2003) compared the quality of argument between face-to-face and computer-mediated discussions using proportions of discourse moves such as agree, clarify, justify, question, and respond. Clark and Sampson (2007, 2008) analyzed students' online argumentation first using a framework which includes claim, ground, rebuttal, support, and query and then ranked the quality of argumentation according to its level of structural sophistication using a five-level hierarchy. Clark et al. (2009) also reported the percentages of each of discourse moves, such as claim, change of claim, rebuttals, clarification to rebuttals, support of a comment, and query. Similarly, Lin et al. (2012) analyzed student online arguments using an analytic scheme that consists of levels 1 – 5 indicating whether they included the key components of an argument, such as claims, evidence, and rebuttals. Investigating the quality of argumentation in online synchronous communication, Alagoz (2013) also reported the statistical frequency of each code of arguments, counterarguments, counter-critiques, counter-alternatives, and agree/disagreement. Taken together, these studies first have tried to identify structural components of online argumentation, focusing on the construction aspect of arguments. Then, considering the importance of rebuttal which is a critique aspect of arguments, studies have evaluated the quality of online argumentation according to the proportions of critical components of argumentation, which is still argumentation structural quality.

Online learning environments have been used as a useful opportunity for students to be engaged in dialogic argumentation beyond what they can achieve in in-class learning environment (Andriessen, Erkens, Van de Laak, Peters, & Coirier, 2003; Clark & Sampson, 2008; Joiner & Jones, 2003; Schellens & Valcke, 2006). The perceived advantage of the online learning environments is that it can be extended beyond the classroom environment. However, there has been few research studies that have examined online discussions where students talked about claims and evidence evolved from their in-class argument-based inquiry. Noroozi, Weinberger, Biemans, and Mulder (2012) argued that "the use of argumentation-based computer-supported collaborative learning (ABCSCL) environment does not necessarily lead to productive argumentation and discussion (p. 82)." They claimed that it is not a simple task to broaden and deepen the space of debate during sequential linear discussion due to the lack of social context cues (ex. physical form, accent, tone of voice, eye contact, and group identity) and complexities and demanding tasks involved in problem-solving activities (Coffin & O'Halloran, 2009). Wendt and Rockinson-Szapkiw (2014) also reported that students in online collaborative activities using the Edmodo educational platform had more science misconceptions than students in collaborative activities in traditional classrooms. They argued that asynchronous environments may make it difficult to effectively negotiate a response. In this respect, students in our study engaged in online asynchronous discussion combined with in-class wrap-up discussion (ODID) with claims and evidence based on their interpretation of data collected during in-class argument-based inquiry. Ford (2008b) argued, "In science as a social practice, critique motivates authentic construction of knowledge that is uniquely scientific (p. 405)." In this regard, our study aimed to examine how ODID along with inquiry investigation contributes to student engagement in the aspects of argument (construct and critique of argument) by analyzing multiple data resources. A research question guiding our study is "How did students engage with the aspects of argument (construct and critique of argument) within online asynchronous discussion combined with in-class wrap-up discussion (ODID) along with argument-based inquiry?" Analysis of multiple data resources, such as online discussion, in-class wrap-up discussion, and students' written claim, and evidence, is used to examine students' engagement with critical components of arguments. Students' written reflections on their experience of online discussion would also provide practical information on what students do while engaged in online discussion.

Methods

Research Context

The participating grade 5 students completed a human health investigation using the argument-based inquiry approach. This was a 6-week unit. Each session was 1 h length, and there were three sessions a week. This study selected the Human Health Investigation as the topic and designed a series of ODID activities to meet the district mandated science curriculum (Iowa State Board of Education, 2015). Each group of students was given a research context, i.e. symptoms of five patients, by their teacher and was asked to do research to diagnose a patient's health problem. Each of the five patients had symptoms of one of the following: leukemia, hyperglycemia, asthma, burns, or stomach ulcer (see supplementary file 1 for an example of the problem context). Each group of two or three students was assigned to one of the five sub-discussion scenarios. As the students were engaged in doing research, they collected information from internet sources on the symptoms of several diseases and analyzed the information from the internet as well as that given by their teacher. They then proposed a claim, that is, a diagnosis of each patient's health problem, and provided evidence supporting their claim. The students were encouraged to negotiate and critique claims and evidence as they presented and shared with others in class (Vygotshy, 1962).

The teacher invited her students to engage in online discussion using the Moodle forum to help them talk with their peers from other classes and to extend their negotiation in class about the investigation. Moodle is a virtual learning environment, and the Moodle forum was used to build collaborative communities of learning in science in this study. Students in this study were able to build a collaborative learning community where they engaged interactively in argumentation via electronic communication, i.e. the Moodle forum. Once students entered the Moodle forum, they were able to see all the questions, claims, and evidence the other students had posted. All the notes that the students posted in the Moodle forum were recorded and saved, so that the students could have time to read, think about, and respond to the postings by their peers. The students were invited to post their claims and evidence in the Moodle Forum using prompts (see supplementary file 2 for the prompts). The teacher asked students to post their group's questions, claims, and evidence for the human health investigation unit, but did not make online discussion an assignment or give a grade for it to the students. Students voluntarily participated in online discussion using the Moodle forum during lunchtime or after school at home. The lunchtime sessions enabled the few students who did not have computers connected to the internet at home to participate in online discussion during lunchtime. In the online discussion, 111 students from the five classes produced 686 notes over the period of a month.

After they completed online discussion, students also engaged in a 1-h wrap-up in-class discussion. The in-class discussion was student-driven. The students were required to make decisions about the claims and evidence being put forward by individuals or small groups. The teacher did not pass judgment on the claims but rather promoted the critical evaluation in order for students to generate rich understanding of the science concepts. Students were able to collectively reach a *consensus* claim(s) and to test these against disciplinary norms. The importance from an epistemic point of view is that students, through the critical evaluation of the claims and evidence, were able to generate a much richer and stronger understanding of the concepts as opposed to being simply told if they are right or wrong. Students initiated the in-class discussion and decided how and what they would do using the guiding frame such as "We should just talk as a whole class and see what we figured out," "So first talk about what happened with the Moodle and …" "So we should just put it on the list and talk about it," "Yeah that's better." The students talked about what happened in the Moodle forum, negotiated claims and evidence for each of the five patients, and built *consensus* on claim for each of the five patients. Then, each of the students wrote his/her final claims and evidence, and a reflection on his/her learning experience. For reflection on online and in-class discussions, the students were given the following prompt: What did you read on the Moodle about your patient? What discussions did you notice peers having about the diagnosis of your patient? What was being negotiated/argued about the diagnosis of your patient? How did the information you read on the Moodle confirm/change/influence your final diagnosis?

Participants

One hundred and eleven grade 5 students from five science classes of three teachers in a rural school in the mid-west region of the USA engaged in scientific inquiry and online discussion. Only one of the three teachers had her students write claims and evidence after online and in-class discussions. The teacher, Mary (pseudonym), had 77 grade 5 students in the 3 science classes, 25 students each in 2 classes, and 27 students in the other class. We were able to collect writing samples from 54 students of the teacher. While 111 grade 5 students from the 5 science classes produced online notes in the online discussion, we were able to collect writing samples after online and in-class discussions from only 54 of Mary's students. We acknowledged that the "human health investigation" was the second activity in which the participant students engaged in using the argument-based inquiry approach. The science classes that students had had in the years before this study were lecture-based and teacher-centered, which did not allow students to negotiate their ideas about and through scientific inquiry. The students worked in groups in the human health investigation using argument-based inquiry approach. Each group of students posted claims and evidence in the Moodle forum, and individual students voluntarily participated in the online discussions on his/her own. Each student had his/her own ID for the Moodle forum and was able to post his/her own response even though it might be different from the other members' ideas in his/her group. In-class wrap-up discussion among all the students after the online discussion was led by a leading student of the class.

The teacher of the participating students was an elementary-trained teacher who had limited science background and experience and 6 years of teaching experience. The teacher did not have experiences of implementing argument-based inquiry approach before she participated in a 3-year professional development program. The program discussed the importance of teaching science through an argument-based inquiry approach and provided experience in several science activities using this approach. The teacher had 2 years of experience in implementing the argument-based inquiry approach in science classes, along with participating in the professional development program, and voluntarily participated in this study. The participating teachers had taught this topic for a number of years and had experienced no difficulties in terms of conceptual level of understanding required for grade 5 students. As framed by the curriculum, the topic is at the broad conceptual level rather than focusing on in-depth content knowledge, that is, the focus of the curriculum is to help students frame understanding of the topic. Students begin to build a conceptual frame that can be enhanced in their later schooling. The teachers as part of planning had constructed concept maps of the topic for which they shared with the researchers as a means of ensuring that the conceptual knowledge discussed in the topic was both appropriate and scientifically acceptable.

Data Collection

This study employed a qualitative research design using online notes, a video record of the in-class discussion after the online discussion, and writing samples of claims, evidence, and reflections produced after online and follow-up in-class discussions. In the online discussion, 100 groups from the 5 classes presented their claims and evidence, with 111 students producing 686 notes over the period of a month. Individual student posts were collected and analyzed in this study. A video record of the 1-h in-class wrap-up discussion included students' negotiation after they completed their online discussions using the Moodle forum. Writing samples, including claims, evidence, and written reflections, were collected from 54 students from three classes after online asynchronous and in-class synchronous discussions.

Data Analysis

Our previous study analyzed online notes in terms of argumentation and reported 7 codes of presenting students' notes and 20 codes of responding students' notes (Choi, Hand, & Norton-Meier, 2014). The in-class wrap-up discussion was analyzed using the same constant comparative method in this study. The total number of the codes assigned to the in-class wrap-up discussion was six (see supplementary file 3 for codes and an example of the coding). As the students were engaged in doing research, they collected information from internet sources on the symptoms of several diseases and analyzed the information from the internet as well as that given by their teacher. "Provide reference resources" means that student provide information on where they got evidence. We define "evidence" as a component supporting "claims" that includes not only data but also data, warrant, and backing of Toulmin (1958)'s components of argument. Evidence posted in the online discussion includes data itself as well as the reasoning that logically links relevant data points in support of the claims being made. Students' written reflections on their learning experience were also analyzed using a constant comparative method and were open-coded without using pre-established categories or codes. We generated a series of codes on the basis of the data, reconsidered these codes through multiple iterations (interactive process) of data analysis, and then formulated organized codes. The total number of codes assigned to the student reflections was seven (See supplementary file 4 for codes and an example of the coding). Then, we examined differences in claims and evidence before and after ODID. We tracked 54 students from two classes with respect to changes in claims and evidence before and after ODID. The first author and a doctoral student independently reviewed all sets of data using preliminary coding scheme. Any disagreement was discussed until consensus was achieved.

Findings

Within ODID along with argument-based inquiry, students (a) used evidence resources to challenge and supplement arguments, (b) critiqued and reinforced evidence, and (c) strongly negotiated and confirmed/revised claims as they engaged with the aspects of argument (construct and critique of argument). These findings were supported by multiple data sources, such as online notes, in-class discussion, and writing samples of claims, evidence, and reflection.

Used Evidence Resources to Challenge and Supplement Arguments

It appeared that the students in this study challenged evidence resources and 23 (43%) of the 54 students, which is the total number of students who reinforced evidence resources in Table 1, supplemented evidence resources as they engaged in ODID. Students were able to confirm or revise their initial claim that they developed through argument-based inquiry, and then support their revised claim or confirm their initial claim by using more resources of evidence. Of the students who used more resources of evidence, 11 were ones who kept the *consensus* claim and 9 were ones who changed the claim to agree with the *consensus*. Only three students were ones who kept the claim which was not the *consensus*. In online discussion, students challenged presented claims, negotiated several claims, and thereby built a *consensus* claim, as they reflected on their experiences of online discussion (see supplemental file 4). There were still 11 students who kept their initial claim after ODID, even when it was different from the *consensus*. While about half of the students, who changed their initial claim to agree with the *consensus* after ODID (9 out of 19 students) and who kept their initial claim if it was the same as the *consensus* (11 out of 24 students), reinforced resources of evidence after the discussions. It is interesting to note that most of the students who kept their initial claim when it was not the same as the *consensus* (8 out of 11 students) did not add more resources of evidence after discussions. This would suggest that there needs to be a space for the teacher to challenge student ideas prior to them writing their claims and evidence.

Students' written reflections on their experience of online discussion also indicated that students recognized the online discussion as an opportunity for getting more evidence resources of evidence, which helped them collect information from multiple sites. Among the 132 codes from student-written reflections, 22 (15.9%) were assigned to the code of "do more research" (see supplemental file 4). For instance, a student commenting, "*The info on Moodle changed my mind because on Moodle, I went on multiple sites and they did match Leukemia more than Mono's symptoms did*," reflected that she was stimulated to do more research. Other students also indicated that they

Table 1 Differences in claims, evidence resources, and evidence after ODID*

Claims after ODID	Number of students	Evidence resources after ODID	Number of students (%)	Evidence after ODID	Number of students (%)
Keep initial claim if it was the same as the *consensus* reached after ODID	24	Reinforced	11 (46%)	Reinforced	6 (25%)
		Same	13 (54%)	Same	18 (75%)
Change initial claim to agree with the *consensus* reached after ODID	19	Reinforced	9 (47%)	Reinforced	9 (47%)
		Same	10(53%)	Same	10(53%)
Keep initial claim even when it was different from the *consensus* reached after ODID	11	Reinforced	3(27%)	Reinforced	1(9%)
		Same	8 (73%)	Same	10 (91%)
Total	54				

ODID online asynchronous discussion combined with in-class wrap-up discussion

were able to visit more websites as the online discussion guided and stimulated them to visit websites other than the ones they had already visited, "*On Moodle, people were arguing about if it is type 1 or type 2 diabetes. When I went to some of their websites, type 2 diabetes is for adults and type 1 diabetes is for kids*." "*There was lots of arguing on Moodle between types of 2nd degree burns. I went to some of the locations and I had to agree with the group that it was 2nd degree burns. I learned that I degree burns do not have blistering too*." The students in online asynchronous discussion monitored and evaluated reliability and sufficiency of resources of evidence and were able to get further information on resources of evidence.

It also appeared that the responding students in online discussion negotiated evidence sources of evidence (106, 15.9%) by "challenging reference source (16, 2.4%)," "requesting more reference sources (11, 1.7%)," "requesting to provide reference resource (35, 5.3%)," and "providing more reference resources (44, 6.6%)" (refer to Choi et al., 2014, for detailed description). For instance, a student requested to provide internet reference resource as he responded to the presented evidence, "*how do you know those are symptoms of second burns and where did you get this evidence*?" The highest portion of the online notes by the presenting students was "providing short answers," which were mostly answers to the students' query about internet sources of evidence (refer to Choi et al., 2014, for detailed description). There was also a code of "provide reference source" in the in-class wrap-up discussion (see supplementary file 3 for codes).

Results from students' written reflections, online discussion, and in-class wrap-up discussion indicate that the students provided and challenged the sources of evidence through the ODID and were able to use more information about sources of evidence (than ones that they had in the argument-based inquiry) after the discussions. Although half of the students in this study used the same evidence sources after discussions with the ones before, we would argue that the students engaged in the discussions were informed by more varied resources of evidence than the ones they had already examined, and some of the students did not add more evidence resources in their writing since adding more resources was not a requirement for writing after the discussions. It is noteworthy that the students in this study used more evidence resources based on their learning from online discussion even though they were not given any direction to provide evidence resources. Overall, the students engaged in the ODID both provided and challenged the internet resources as evidence basis, and this led 43% of the students to supplement evidence sources when they proposed claims and evidence after the discussions. This implied that the students were deeply engaged with the critique of argument in the ODID along with argument-based inquiry.

Critique and Reinforce Evidence

As shown in Table 1, it appeared that 16 (30%) of the 54 students in this study reinforced and articulated evidence as they engaged with critique of evidence in the ODID. Nine (47%) of 19 students who changed his/her claim to agree with the *consensus* and 6 (25%) of 24 students who kept the *consensus* claim reinforced and articulated their evidence using more sets of data or critical data to support the claim after ODID. Most of the students who provided more evidence were ones who changed their initial claim to agree with the *consensus* after the discussions or who kept their initial claim if it was the same as the *consensus*. This meant that ODID helped the students confirm their initial claim or revise their initial claim and then support their revised claim or confirm their initial claim correctly using more articulated and reinforced evidence. While 6 of the 24 students who kept the *consensus* claim and 9 of the 19 students who changed his/her claim to agree with the *consensus* claim reinforced evidence, it is interesting that almost all students who kept the claim that was not the *consensus* even after the discussion (10 out of 11 students) provided the same evidence or simply asserted that the claim was correct. There was also one student who kept the claim that was not the *consensus* even after the discussion and reinforced his evidence. His reflection implied that he ignored the critical symptom, i.e. high white blood count although he identified it on the Moodle post and justified his claim that more symptoms were matched in his diagnosis (see supplemental file 5). It is evident that the students reinforced and articulated the evidence by adding the critical aspect of the evidence after the discussions, and that evidence became more sufficient and valid compared to before the discussions (see supplemental file 5).

The results indicated that students in online asynchronous discussion were engaged in the critique of evidence in terms of sufficiency, validity, reliability, or accuracy, as indicated by the code of "challenge evidence" (refer to Choi et al., 2014, for detailed description). The students also reflected on online discussion as opportunities to critique evidence. Among the total 132 coded reflections, 28 (20.3%) were assigned to the code of challenge evidence (see supplemental file 4). For instance, a student reflected as follows:

> First I talked to my group members. They thought it was lymphoma but they didn't have a match for a high white blood cell count … we were arguing about a high blood cell count. They thought it didn't matter if a high white blood cell count matched or not. I said that she did or that wouldn't match her symptoms.

Of the coded students' reflections, 12 (8.7%) were assigned to the code of "get more evidence." A student also reflected on online discussion, "*It helped me gather information* *from the websites they labeled.*" The codes of get more evidence and challenge evidence from student reflections indicated that online discussion helped the students to critique their evidence, and then they were able to articulate and reinforce evidence.

The argument codes identified from online discussion also supported the results from students' reflection. The students who responded to the presented claims and evidence focused on negotiating evidence by "challenging evidence" in terms of sufficiency, reliability, validity, and accuracy (163, 24.5%), "requesting more evidence" (30, 4.5%), or "querying backing" (35, 5.3%) (refer to Choi et al., 2014, for detailed description). It appeared that students focused on challenging evidence (24.5%) as they responded to the presented claim and evidence. The students also did "support evidence" (47, 7.1%) or "provide more evidence" (44, 6.6%) when they agreed with a claim. In total, 47.9% (319) of the total 666 coded notes by the responding students were focused on evidence. The presenting students also actively responded to the evidence critique by justifying, clarifying, and providing more evidence. About 46% (70) of the total 154 coded notes by the presenting students were identified as dealing with evidence (refer to Choi et al., 2014, for detailed description).

It also appeared that the students engaged in the evidence critique by challenging and providing evidence in the in-class wrap-up discussion. Of the total of 67 coded in-class wrap-up discussions, 55 (72.1%) were about evidence, such as challenge evidence (28.4%) and provide evidence (53.7%) (see supplemental file 3). For instance, a student critiqued evidence about the Mononucleosis and Lymphoma in that they did not match with the symptom of abnormally high white blood cells.

> Could it be something different then, since it's the abnormally high white blood cell count, because it's kind of a big deal. And if you didn't find it in both (Mononucleosis and Lymphoma), then it should look a little different (Leukemia).

In response to a question, "*So what did you say that mono was?*" a student during the in-class wrap-up discussion provided evidence, "*Mono has loose legs, loss of appetite, and* ..." The codes of challenge evidence provide evidence from in-class wrap-up discussion also indicated that in-class wrap-up discussion helped the students to critique their evidence, and then they were able to articulate and reinforce evidence.

While the majority of the students who kept the *consensus* claim or who changed his/her claim to agree with the *consensus* claim used the same evidence as the one before discussions, it is meaningful that 30% of the students reinforced evidence through online discussion and in-class wrap-up discussion even though their teacher did not request them to reinforce evidence in writing after the discussions. It appeared that students' critique of evidence during online discussion and in-class wrap-up discussion, as indicated by the codes of challenge evidence request more evidence, "support/provide evidence," "justify," and "clarify" resulted in evidence reinforcement and articulation after the discussions (refer to Choi et al., 2014, for detailed description).

Strongly Negotiate and Confirm/Revise Claims

As shown in Table 1, among the 54 students, 24 (44.4%) had the same claim before and after ODID, which was the *consensus* among the students at the class discussion. Each of these students had confirmed that his/her initial claim was correct by means of the discussions and kept the initial claim if it was the same as the *consensus* reached after discussions. Another 19 (35.2%) students changed his/her claim to agree with the *consensus* claim, and 11 (20.4%) students kept his/her claim when it was not the *consensus* after the discussions. In summary, 43 among the 54 students went with the *consensus* claim by keeping the claim or changing his/hers to agree with the *consensus* claim after ODID.

Results from student online notes, in-class wrap-up discussion, and reflection supported that the students were able to confirm/revise their claims by means of the ODID (see supplementary file 6). Some students changed their claim to agree with the *consensus* after the discussions and used a different reference resource and added backing. The students in this study reflected that they were able to confirm their claim or revise the claim by means of the discussions. Of the 132 codes developed from student-written reflections on the online discussion, 23 (16.7%) were assigned to "confirm/change claim" (see supplemental file 4). The students indicated that they were able to confirm their claim based on the information posted on the Moodle forum as follows:

> The information on the Moodle confirmed my claim and evidence.
> Then information that was on Moodle confirmed me that Elliot has second degree burn.

The students also reflected that they were able to "build *consensus* on claims" (9, 6.5%) through ODID. For example, a student reflected that they all agreed and built *consensus*, "*We all agreed that leukemia was what Alexia had but what gave it away was leukemia was the only disease that explained her high white blood cell count.*"

Further, the students perceived the online discussion as an opportunity to negotiate and challenge several claims proposed by their peers. Of the 132 coded reflections, 40 (28.9%) were assigned to "negotiate several claims." Of the total coded reflections, 4 (2.9%) were assigned to "challenge claim" (see supplemental file 4). The students reflected that they were challenged to propose a detailed claim, that is, more specific diagnosis on a patient through online discussion. For example, one student reflected that her friend challenged her to provide a detailed claim as follows:

> Karen asked me a great question it was "I agree she has asthma but what kind does she have." So then I went on webmd and Kidshealth ad looked up exercise-induced…

The process of negotiation through the Moodle online and in-class wrap-up discussion was described well in the following excerpt of a written reflection produced by a student in this study. She indicated that her experiences of the online and in-class wrap-up discussions enabled her classmates to negotiate to build a *consensus*. The online discussion stimulated her to do more research and collect more information so that she could confirm or revise her claim. She finally revised her claim into a valid one based on extra evidence collected from additional evidence resources.

Results from online notes also supported that the students were able to confirm or revise his/her claim through online discussion. Among the total of 666 coded notes by the students who responded to the presented claims and evidence, 192 (28.8%) were assigned to the codes related to negotiation of claims, such as "agree with claim (30, 4.5%)," "disagree with claim (27, 4.1%)," "propose a counter-claim (46, 6.9%)," or "simply agree or disagree (40, 6.0%)" (refer to Choi et al., 2014, for detailed description). The code of "agree/disagree with a claim" was assigned to the note that supported or challenged evidence, which was different from the code of simply agree or disagree without supporting or challenging evidence. Also, 16 (10%) of the total 154 coded notes by the presenting students in online discussion were assigned to "accept challenge" (refer to Choi et al., 2014, for detailed description). For instance, a presenting student who claimed Daria's health problem was Transient Global Amnesia accepted challenges and changed his claim as follows:

> I now see that this claim is wrong … I now think that that is Hypergycemia. On www.mayoclinic.com I found out that Hypergycemia causes high glucose levels and causes weight loss, disorientation, blurry vision, and becoming tired and thirsty for no apparent reason.

Results from online notes also supported that the students challenged each other. Among the total of 666 coded online notes, 49 (7.4%) were assigned to the code of "challenge claim" (request to propose a detailed claim) (refer to Choi et al., 2014, for detailed description). Further, results from the in-class discussion supported that the students challenged claims during the in-class discussion. Among the total 67 coded in-class discussions, 2 (2.9%) were assigned to the code of "request to propose a detailed claim." For instance, a student asked to propose a detailed claim as follows: *what type of asthma do you think it is?* The students also negotiated several claims during the in-class discussion. Among the total 67 codes from wrap-up in-class discussion, 3 (4.5%) were propose a counter-claim, and 5 were "present a claim" (see supplemental file 3).

While there were still some students who kept his/her claim when it was not the *consensus* after ODID, it is meaningful that the majority of the students (43 out of 54) took the advantages of ODID by keeping the claim or changing his/hers to agree with the *consensus* claim after the discussions. It appeared that students' active critique on several proposed claims, as indicated by the codes of agree with claim, disagree with claim, propose counter-claim, challenge claim, and "request a detailed claim" from online discussion and in-class wrap-up discussion and the ones of challenge claim, negotiate several claims, "build *consensus* on claims," and "confirm/change claim" from student reflection, enabled them to build a *consensus* and confirm and/or revise their claims after the discussions. This implied that the students were deeply engaged with both construct and critique of claims in the ODID along with argument-based inquiry and took advantages of the whole process.

Discussion

In addressing our research question, we would conclude that online asynchronous discussion combined with in-class wrap-up discussion along with argument-based inquiry engaged grade 5 students in the construct and critique of claims and evidence in that they used evidence resources to challenge and supplement arguments, critiqued and reinforced evidence, and strongly negotiated and confirmed/revised claims. Our study provides rich information on how ODID along with inquiry investigation engaged students with both the construct and critique of claims and evidence. While much has been written about older students (Keys et al., 1999; Nam, Choi, & Hand, 2011; Sampson et al., 2011), this study begins to highlight how younger students when given opportunities of the type described are able to richly engage with the fundamentals of science argumentation, while at the same time engaging with science conceptual knowledge about health. Our conclusion was supported by results from multiple data resources, such as online discussion, in-class wrap-up discussion, student-written reflections on the experience of online discussion, and student-written claim and evidence.

This study is important in that it enables us to see how pedagogical opportunities that focus on building argument not as some structure to be completed but as an epistemic tool (Cavagnetto, 2010) can be reinforced through the use of online discussion. The findings of this study explain in detail which component of argument and how is enhanced in the combined approach of online and in-class discussions beyond argument-based inquiry. Given that other studies have struggled to get students to make these connections (Clark et al., 2007; Noroozi et al., 2012), this study indicates that when given opportunities to be active participants in the argumentative process, i.e. the combined approach of online and in-class discussions beyond argument-based inquiry, then even young students are able to fully engage with the role of evidence, and the claim and evidence relationship (Choi et al., 2013). Students in this study were able to take the argument framework and the critique of claims and evidence that were parts of argument-based inquiry and adopt these for the ODID. This study is important in that it has shown that students were able to engage in the construct and critique components of argument as a part of their own learning. Students need to be able to both know and use the epistemic practices appropriately in order to fully understand the role of argument in advancing science. As supported by social constructivism (Doise et al., 1975; Vygotshy, 1962), ODID along with argument-based inquiry has provided evidence that students built the foundations for continued use as they advance in school.

The Moodle online forum provided students with opportunities for sharing and monitoring evidence resources, evidence, and claims produced by their colleagues from argument-based inquiry investigations of three classes and allowed them to engage in challenging resources of evidence, critiquing evidence, and negotiating claims. Further, it led students, in particular those who kept their claim if it was the same as the *consensus* or changed to agree with the *consensus*, to reinforce evidence and supplement evidence resources after ODID. We would argue that the ODID along with argument-based inquiry has the significant potential for student engagement in construct and critique of claims and evidence. The students' experiences of negotiating, building a *consensus* on claims, and confirming and revising claims would guide them to appreciate critique and negotiation as a crucial component for construction of scientific knowledge. The students indicated, in their reflection on the experiences of the online discussion, that the Moodle online forum combined with in-class wrap-up discussion enabled them to evaluate, critique, and challenge sufficiency, accuracy, reliability, and validity of evidence resources and evidence. According to Noroozi et al. (2012), a completely explicit argument for learners' knowledge construction in argumentation-based computer-supported collaborative learning (ABCSCL) would comprise a claim with grounds that warrant the claim and a limitation of its validity.

In this respect, students' critique and reinforcement of evidence in this study would be an indication that the ODID when incorporated with the in-class argument-based inquiry approach was beneficial for in terms of the quality of students' argument. Noroozi et al. (2012) and Wendt and Rockinson-Szapkiw (2014) argued that online discussion environments may make it difficult to effectively negotiate a response (Coffin & O'Halloran, 2009). However, in this study, ODID was in addition to argument-based inquiry rather than a substitute for in-class discussion within argument-based inquiry. The findings of this study, i.e. students' challenging and supplementing resources of evidence and critiquing and reinforcing evidence, resulted from students' deep engagement with the construct and critique of argument in the ODID as they completed the human health investigation in class and constructed claims and evidence on their own based on their data collection and interpretation (Golanics & Nussbaum, 2008). We would argue that argument-based inquiry encouraging negotiation was important in guiding students to continue to use the construct and critique of argument in the ODID.

About 80% of the students ended up proposing the *consensus* claims after ODID. Results from the online notes and student reflection indicated that students confirmed or revised their claims by challenging claims, negotiating on several claims, and building *consensus* through ODID. It is also interesting that most of the students who provided more resources of evidence after ODID were ones who changed their initial claim to agree with the *consensus* after the discussions and who kept their initial claim if it was the same as the *consensus*. These results support previous studies which reported that students learn science while they are engaged in critique and negotiation about their inquiry investigations in both oral and written forms (Ford, 2008a, 2008b; NRC, 1996).

We would like to reiterate that the students in this study completed the human health investigation in class using an argument-based inquiry approach, where they did construct and negotiate questions, claims, and evidence. The argument-based inquiry approach provides teacher and student templates to promote student active negotiation of claims and evidence. What students communicated in their science classrooms may shape their ODID as norms, for instance, critique a claim as a product of data analysis and evaluate evidence as a means to sufficiently support claims. It appeared that the patterns identified in the online discussion are related to students' experiences and practice of negotiation using an argument-based inquiry approach in class before engaging in the online discussion. The student-written reflections in this study indicated that the online discussion allowed students to share norms of scientific practice that they developed in class in the argument-based inquiry approach before they engaged in the online discussion and further assimilate them in the in-class wrap-up discussion (Andresen, 2009). It appears that the ODID was a beneficial addition to the in-class argument-based inquiry approach.

Online discussion provides students, in particular, those who are accustomed to traditional ways of learning science, with an opportunity and the support they need for argument in scientific inquiry. The engagement in ODID teamed up with an argument-based inquiry investigation can be an effective way for students to refine their ideas, to develop a sense of the criteria for evaluating evidence as an essential argument component supporting the claims, and to construct a conceptual framework on science concepts. Our study suggests that online discussion should be incorporated with an in-class argument-based inquiry approach instead of being used as a single way to promote students' arguments. As claimed by Joiner and Jones (2003), comparing the quality of face-to-face argumentation with online discussion, the latter would encourage students to be more thoughtful and use more references. In this respect, this study implies that incorporating ODID with in-class inquiry investigation instead of simply using argument-based inquiry in class or solely using online discussion has a significant potentiality for students' learning science. Students should be encouraged to take ownership of their learning in ODID added to an in-class argument-based inquiry, which means that students will think carefully about central questions and about related data/information, and will reach an understanding of key ideas with claims and evidence. This study has limitation in that the writing samples of claim, evidence, and reflection after the discussions were only from 54 students out of 111 students who engaged in online discussion. Further studies are needed on students' negotiation on claims and evidence related to scientific concepts and higher-grade students' argumentation. These studies would probably suggest what students should be given for authentic learning of scientific concepts and practice of negotiation.

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